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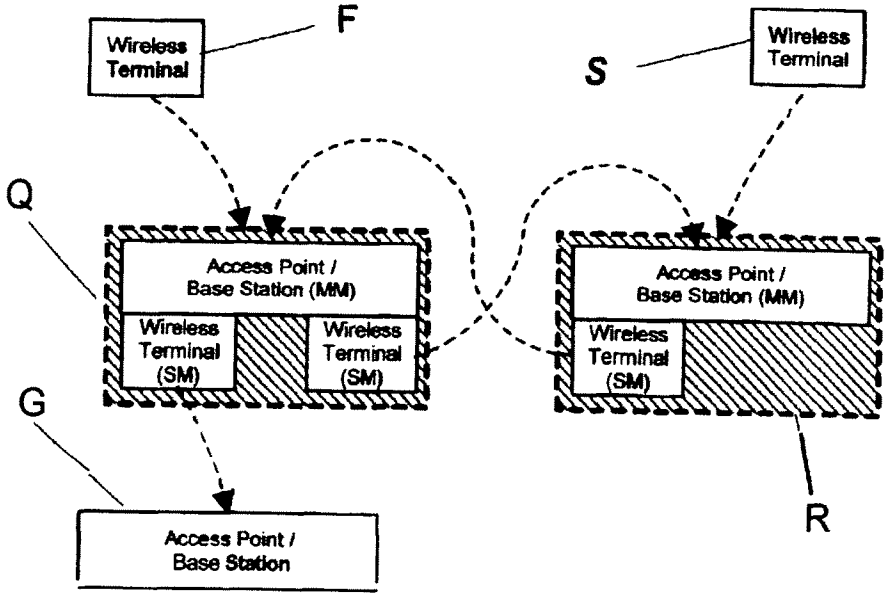

(57) Abstract: A network node (N, O, P, Q, R, U) arranged to act as a communications hub between a first set of devices (F) and a second set of devices (G, R, S), wherein the node (N, O, P, Q, R, U) comprises master means (MM) and servant means (SM) and wherein the master means (MM) is arranged to co-ordinate data transmissions between the node (N, O, P, Q, R, U) and the first set of devices (F), and wherein the servant means (SM) is arranged to be co-ordinated by another network device (G, R) for data transmissions between the node and the second set of devices (G, R, S).

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METHOD AND DEVICE FOR CONNECTING SETS OF DEVICES

INTRODUCTION

The present invention relates to electronic device/computer/telecommunications networks. The networks are provided to transmit data/information and/or share information and/or resources across the network.

The invention is applicable to networks which use wireless/wired methods for transmission. However, specific embodiments will be particularly advantageous to Wireless Local Area Networks (WLAN or LAWN), a sub-class of Local Area Networks (LANs) which use high frequency radio waves (wireless) rather than wires for communication between certain network devices. For simplicity, subsequent discussions will be mainly limited to the field of wireless computer area networks.

As computer networks can be categorised in a number of ways, for example, in terms of topology (geometric arrangement of devices in a network e.g. bus, star, mesh and ring), media (the means by which devices are connected e.g. co-axial/fibre optic cables or radio waves), protocol (a common set of rules for sending data e.g. Ethernet), geographical distribution of the network (e.g. local area, wide area and metropolitan area) or architecture (peer/peer or client(servant)/server(master)), it is possible that such simple categorisation often leads to a computer network falling into more than one category. Although the present invention relates to computer networks regardless of the topology, media, protocol, geographical distribution or architecture of the network, the present invention is particularly applicable to the so-called area networks and mesh networks. Furthermore, the invention will be particularly suited to networks which use peer/peer and/or client/server relationships between devices to control network transmissions.

Although specific embodiments of the invention relate to local area wireless communications networks and the routing of information between the nodes of such networks, and particularly to a method and apparatus for establishing and maintaining such wireless networks, the advantages provided by the invention would also be

applicable to cellular telecommunications networks for mobile telephony and/or data-rich services.

The use of wireless technology for the communication of digital data is well known. Each wireless technology constrains the amount of data that can be sent in a given time as measured by the "data-rate". Generally, technologies with high data-rate are able to communicate only over shorter distances. For example, current Wireless Local Area Network technologies typically transfer several million bits per second over distances of ten of meters. New Wireless Local Area technologies will allow data-rates of tens or even hundreds of million bits per second. However, the distance of communication will be reduced and the signals will be more constrained by walls and other physical barriers and by interference between neighbouring cells/zones. Specific aspects/embodiments of the invention relate to a method and apparatus that allows a plurality of wireless devices to work collectively in a mesh to increase the coverage area while maintaining high data-rate operation.

While the concept of mesh connected wireless networks is known, the use of such networks in local area networks has only been considered recently. The present invention includes a method for implementing each node in such a mesh so that a single radio device at each node can replace multiple radio devices in creating the mesh. Specific embodiments of the invention allow each node to act as a plurality of logically independent virtual devices operating through a single wireless interface. This simplifies management and allows the network to scale up as more nodes are added. Furthermore, as an implementation example, specific embodiments of the invention allow a wireless network built according to the IEEE802.11 standard to be implemented as a mesh while still retaining compatibility with standard conformant devices which do not incorporate the invention.

SUMMARY OF THE INVENTION

According to a first aspect, the present invention provides a network node arranged to act as a communications hub between a first set of devices and a second set of devices, wherein the node comprises master means and servant means and wherein

the master means is arranged to co-ordinate data transmissions between the node and the first set of devices, and wherein the servant means is arranged to be co-ordinated by another network device for data transmissions between the node and the second set of devices.

The node according to the present invention co-ordinates data transmissions between (to/from) the node and a first set of devices. However, data transmissions between the node and a second set of devices are not co-ordinated by the node but are under the co-ordination of another network device. Thus, a node is provided which has both master/servant and servant/master architecture according to which set of device the node is dealing with. Accordingly, the node is not limited to connection to one type of master/servant device but can be connected to both types, and thus the node can be connected to other nodes without having to consider its specific architecture. This greatly facilitates that creation of a mesh network. The node is also able to operate in both infrastructure and ad hoc modes.

Simple management of network data transmission is provided, with a master for each set of devices. Such a hierarchical architecture allows data transinission to be prioritised according to policy considerations, such as importance of a respective data transmission or minimising interference in data transmission to the respective set of devices. Such an arrangement allows the prioritising of time sensitive data by using, for example, polled (network devices inform the node of the type of data they wish to send using short messages and the network node selects which device may send the data, starting with the highest priority traffic first), slotted (the node reserves time slots for each network device to send data and the network devices are informed that they may only send data during the certain time periods) and/or weighted contention (the network devices listen for a quiet period and then send data – with high priority data the network devices are configured to wait shorter intervals before starting to send the data during quiet periods) methods. The invention may use any of the priority control methods in IEEE802.11 , or more specifically, IEEE802.11e.

In the case where one or more of the first set of devices conform to a Network Standard, e.g. IEEE802.11 , the network node master means may be said to control

data transmissions between the node and the devices conforming to the Standard as such Standard conforming devices will be arranged to obey the network node master means. Similarly, if the network node according to the present invention is arranged to conform to a Standard, e.g. IEEE802.11, then the network node servant means may be arranged to be controlled by another network device for data transmissions between the node and the second set of devices. In preferred embodiments, the master means is arranged to control data transmissions between the master means and the first set of devices, and/or the servant means may be controlled by another network device for data transmission between the node and the second set of devices.

Preferably, the another network device is a neighbouring network device, such as one within the vicinity for wireless communication in an area network. Alternatively, the another network device may be remote to the network device according to the present invention, such as outside the WLAN.

Preferably, the neighbouring network device is a second network node arranged to act as a communications hub for one or more sets of devices, and wherein the first and second network node are arranged to co-ordinate/control data transmissions to diminish data transmission interference between the various sets of devices. The second network node may also be a node according to the present invention, but may be a node with just master means, and not both master and servant means.

Preferably, the network node comprises detection means arranged to detect the presence of one or more neighbouring second sets of devices, and apportion a corresponding number of servant means to be co-ordinated/controlled by each neighbouring second set of devices.

Preferably, the node comprises detection means arranged to detect the presence of one or more neighbouring network nodes each co-ordinating/controlling a set of devices, and wherein the node is arranged to apportion a corresponding number of servant means to be co-ordinated/controlled by each neighbouring network node.

Preferably, this apportioning of a corresponding number of servant means is done dynamically, as and when neighbouring second sets of network devices/nodes are detected by the detection means.

Preferably, the node master means and the or each servant means each have a different network address. This allows the master and the or each servant means to operate independently. Each servant means is not physically independent but may be said to be logically independent (i.e. each being a virtual device). The network address may be administered locally, and may be the MAC address. The network address for each servant means may be created dynamically, as and when neighbouring second sets of network devices/nodes are detected by the detection means.

The dynamic creation of servant means is particularly facilitated by the creation of the or each servant means in software. It is also particularly advantageous for each of the servant means to share the use of the same transmission hardware e.g. the wireless transmission means.

The master/servant means may be implemented in hardware, software or a combination thereof. The degree to which the master/servant means is implemented in hardware/software may be determined by considering cost and/or operation speed, for example, modestly compromising speed for reduced cost. The hardware may be an integrated circuit incorporating a processor, which when programmed with appropriate software (stored on a memory, which may be integrated with or external to the processor) controls the operation of the network node to have master/servant functionality as described. The hardware may be specifically adapted to run software implementing the master/servant means.

The master/servant means preferably comprises memory means which is used as a buffer store to store data transmissions until the data transmissions are authorised for continued transmission.

Preferably, master means and the or each servant means are arranged to pass data between one another. This may be directly (data transmission staying within the network node) or indirectly (data transmissions exiting the network node). Preferably, the network node is arranged such that the data passed between the master and the or each servant means stays within the network node. Preferably, a MAC bridge is provided to allow data to pass between the master means and the or each servant means.

The first and/or second set of devices may comprise one, two or more devices, and may be one or more network nodes, which may be the same or different to the node according to the present invention. Furthermore, although the node according to the present invention acts as a communication hub between a first and second set of devices, the node may also act as a communications hub for data transmissions within the first set of devices when the first set of devices comprises a plurality of devices (possibly with no second set of devices). In addition, the node may be arranged to also utilise the data transmissions for node specific functions e.g. in the case where the node is an electronic device, such as a home entertainment (music/video) system, which can play the music/video transmitted to it from a network-connected home computer as well as transmit the music to another network-connected home entertainment system in an adjacent room/building.

Transmissions between the node and the first/second sets of device may be by wired transmission paths. However, the node preferably comprises wireless transmission means for wireless transmission between the node and the first set of devices. Preferably the node comprises wireless transmission means for wireless transmissions between the node and the second set of devices. Preferably, the same wireless transmission means is used for wireless transmissions between both the first and second set of devices. Preferably, the wireless transmission means comprises hardware, and includes radio transmission functionality. The radio transmission functionality may include one or more antennas.

The network node is preferably an access point device conforming to the IEEE802.11 standard, in particular with the master means arranged to conform to this standard.

The network node may be a mobile telecommuncations network device, for example a cellular base station.

In a second aspect, the invention provides a network comprising the network node according to the first aspect of the invention.

Preferably, the second set of devices comprises a second network node arranged to co-ordinate/control data transmissions between the first network device servant means and the second set of devices, and the first network device servant means is arranged to be co-ordinated/controlled for data transmissions between the first and second network nodes by the second network node.

Preferably, the second network node also comprises master means and the second network node master means is arranged to co-ordinate/control data transmissions between the second network node master means and the first network node servant means.

Preferably, the network is arranged such that data transmissions between the node and the first and/or second set of devices may travel directly between the node and first and/or second set of devices, or may travel indirectly i.e. with one or more intervening devices/nodes between the set of devices and the node.

Preferably, the network is a computer network and the node is an access point device and the first sets of devices may be one or more wireless terminals. Preferably, the access point device comprises master means provided by base station functionality. The network may be an area network, such as a local area network which may be contained within a home or building. The network node may be an electronic device with other functionality, such as home entertainment functionality.

Preferably, the one or more devices/nodes in the network are arranged to be compatible with the IEEE802.11 Standard.

The network may be a telecommunications network and the node a cellular base station, and the first set of devices may be one or more portable telecommunications handsets.

According to a third aspect, the present invention provides a method of providing network connectivity between a first and second set of devices connected by a network node and wherein the node is provided with the facility to co-ordinate data transmissions with the first set of devices and have data transmissions with the second set of devices co-ordinated by another network device.

In a fourth aspect, the present invention provides a method of generating a mesh network by providing a network node arranged to act as a communications hub between a first set of devices and a second set of devices, wherein the node comprises master means and servant means and wherein the master means is arranged to co-ordinate data transmissions between the node and the first set of devices, and wherein the servant means is arranged to be co-ordinated by another network device for data transmissions between the node and the second set of devices.

A network node, network, method of providing network connectivity, or method of generating a mesh network modified mutatis mutandis according to any of the previously or subsequently mentioned embodiments/aspects of the present invention are also within the scope of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1. Shows a schematic of the structure of a typical wireless device;

Figure 2. Shows one type of organisation for a wireless local area network (infrastructure mode);

Figure 3. Shows an alternative organisation for a wireless local area network (ad hoc mode);

Figure 4. Shows an example of a wireless mesh network;

Figure 5. Shows three nodes implemented according to the invention and forming a simple mesh network (with the dashed arrows representing the hierarchical reporting relationship);

Figure 6. Shows a conventional wireless LAN network into which a node implementing the invention has been introduced;

Figure 7. Shows a portion of the network of Figure 6 comprising a mixture of conventional wireless LAN devices and devices implementing the invention;

Figure 8. Shows an example of a preferred embodiment;

Figure 9. Shows an example of the logical internal organisation of a device incorporating the invention in a preferred embodiment;

The following figures are provided to aid the understanding of a second invention and specific embodiments of the first invention.

Figure 10. Shows a representation of two periods that alternate in time;

Figure 11. Shows the topology of a typical Wireless LAN;

Figure 12. Shows two Wireless LANs operating in proximity;

Figure 13. Shows a group of base stations connected together in a mesh;

Figure 14. Shows an allocation ring which has been divided into three time periods;

Figure 15. Shows two allocations rings and shows how the time periods are allocated to avoid interference between two devices;

Figure 16. Shows how the assignment of the periods changes as more resources are deployed;

Figure 17. Shows a problem that would be created if resource use increases to create an overlap zone between the two allocation rings;

Figure 18. Shows the solution to the overlap problem by using a "no transmit" period;

Figure 19. Shows the state of two allocation rings in the preferred embodiment including beacon positioning;

BACKGROUND TO THE INVENTION

A typical network node in a wireless communications network is implemented as shown in Fig 1. The wireless parts are contained within a node 'A' that might employ a number of other functions. Those functions relevant to wireless data transfer are shown in block 'E'. The wireless communication is effected through a combination of an antenna 'C', some radio electronics 'B' and a wireless network protocol manager 'D' typically implemented as a combination of software and hardware (software, processor, memory).

According to some standard implementations such as IEEE802.11, two modes of network operation may be used. Fig 2. shows operation in *infrastructure* mode whereby all wireless terminals 'F' first connect to a base station 'G' and then messages are routed via the base-station. As an alternative the network can operate in *ad-hoc* mode as shown in Fig 3. whereby the wireless terminals 'F', 'H', 'I' and 'J' attempt to communicate directly. Note in Fig 2. that stations 'J' and 'F' are unable to communicate due to being too far apart for the radio signal to propagate.

PREFERRED EMBODIMENTS OF THE INVENTION

The present invention is embodied in a method and apparatus whereby wireless nodes can form an extended mesh network as depicted in Fig 4. All nodes in the extended mesh can communicate either directly or indirectly with each other thus avoiding the problem where the range is too short for communication. For example node 'K' is able to communicate with node 'M' by communicating first to node 'L'. This type of forwarding mesh is, in itself, not novel. However, the invention relates to a new way in which the mesh is implemented using relationships between the nodes based on the approach shown in Fig 2. In Fig 2 each wireless terminal such as 'F' has a single defined relationship with the base-station 'G'. Such a relationship has the benefit that it allows effective management of the link between 'F' and 'G'. However, in a typical mesh network as shown in Fig 4 nodes such as 'L' have relationships with multiple other devices creating a management problem.

According to this invention, the implementation of the nodes in the mesh network is organised as shown in Fig 5. Each node such as 'N', 'O' or 'P' comprises a combination of one base-station function (MM) and at least one wireless terminal function (SM) operating in a logically independent manner. The number of wireless terminal functions (SM) implemented in the node is dynamic and can be varied according to the required number of neighbours connections in the mesh. Fig 5. shows an example where there are three members to the mesh. In this case each member provides a base-station function (MM) and two wireless terminal functions (SM). Each wireless terminal function (SM) connects to the base-station function (MM) of a neighbouring node using an appropriate wireless protocol. Each wireless terminal function (SM) has a separate network address created uniquely within the mesh network to allow it to operate independently.

By implementing the network as shown in Fig 5. full mesh connectivity is established using logical links that have a simple and well defined relationship to a neighbour node. The implementation of the nodes would, in a typical implementation, be such that the wireless terminal operation (SM) would be performed in software by the Network Protocol Manager ('D' in Fig. 1). This allows a potentially large number of wireless terminal relationships to be established in a complex mesh without adding any additional hardware and by using a single radio and antenna ('B' and 'C' in Fig 1).

A preferred embodiment of the invention is a network conforming to the IEEE802.11 wireless standard (ISO-IEC8802-11 ANSI-IEEE std 802.11-1999edn). Such networks have been widely deployed but do not inherently support mesh connectivity. The configuration of a typical IEEE802.11 network is illustrated in Fig 2. The network comprises two classes of device: Wireless Terminals and Access Points. The Access Point 'G' provides co-ordination functions of the wireless network and also acts as a forwarder for data between wireless terminals or to an attached non-wireless network. Typically the access point is a fixed device. The wireless terminals are devices which desire wireless connectivity either to other wireless terminals or to a non-wireless network. A wireless terminal may be either fixed or mobile depending on the

application. In a conventional network, a device operates either as a wireless terminal or as an access point.

In the preferred embodiment, a new type of device is introduced that simultaneously supports an access point function and one or more wireless terminal functions. This is shown as 'Q' in Fig 6. In Fig 6. the Wireless Terminals such as 'F' are conventional IEEE802.11 devices not incorporating the invention. The Access Point 'G' is also a conventional access point not incorporating the invention. Note that Wireless Terminal 'F' is connected to the access point function (MM) of node 'Q' as if it were a conventional access point. Note that the Wireless Terminal function (SM) of node Q is connected to the access point 'G' as if it were a conventional Wireless terminal. Device Q is able to relay data between Wireless Terminal 'F' and access point 'G'.

Now consider the introduction of a second node incorporating the invention. This is shown in Fig 7 as node 'R'. Node 'R' is within range of node 'Q' and therefore, according to the invention, each node Q, R creates a new logical Wireless Terminal (SM) and connects to the access point function of the other node. Node 'R' is not within range of access point 'G' and therefore does not create a Wireless Terminal for connection to 'G'. Node 'R' can act as an access point (MM) to other conventional Wireless Terminals such as 'S'. Data from 'S' to 'G' can be passed via nodes 'R' and 'Q'.

In this preferred embodiment all devices shown in Fig 7. operate on the same radio frequency and nodes 'Q', 'G' and 'R' all have the same SSID (Service Set Identifier) value as defined in the IEEE802.11 standard.

This embodiment allows the creation of an arbitrary mesh network between nodes incorporating the invention in such a way that conventional devices which do not incorporate the invention can inter-operate in the normal fashion. Because the wireless terminal functions (SM) in the Nodes 'Q' and 'R are implemented using software, the solution can be scaled up to a larger number of nodes without adding any additional hardware.

In the context of a wireless network conforming to IEEE802.11 standard and using terminology defined therein an example of a preferred embodiment would be implemented as follows: An example node 'U' incorporating the invention is shown in Fig **8.** This node is designed both to provide a forwarding node in a wireless mesh network via antenna 'T' and also, optionally, to connect to a local computer 'V' via a wired connection.

When node 'U' is first powered on, it instantiates an STA (Station) function acting as a terminal. This STA function scans the available radio frequencies using beacons or probes to find an access point with the appropriate SSID value. By this method the logical STA discovers the presence of both conventional access points and also other nodes incorporating the invention, here after called 'meshnodes'. A mesh node can be distinguished by the presence of a proprietary information element within the beacon message. If any other mesh nodes are discovered during the scan, the new node 'U' should adjust its radio to a frequency where other mesh nodes are operating and should instantiate, in software, a logical STA function for each mesh node seen on that frequency and should then cause each STA instantiation to authenticate and associate with the AP function in the other mesh nodes.

After a delay for the associationprocess to complete, the new node 'U' will instantiate an access point function (MM) and start to issue beacons. After this it will then instantiate an STA function (SM) for every conventional access point on the same frequency detected during the scan and will attempt to authenticate and associate to each said access point. At the end of the initialisation phase the new node 'U' may have a several STA instantiations (SM), each associated either to another mesh node or to a conventional access point. It will also have an access point function operating which may accept associations for other conventional stations and may attract association attempts from mesh nodes which subsequently start up or come into range. An example of such logical connections is shown in figure **9.** Here there are five STA instantiations (SM), such as 'W', each associated with an AP through the single radio and antenna 'T'. There is a single instantiation of an access point 'X' (MM), also communicating through antenna 'T'. The data passing between these instantiations is connected, in this example, through a MAC bridge device which implements mesh

connectivity using a mesh management protocol such as IEEE802.1d spanning tree algorithm. The MAC bridge also connects to the wired LAN interface hardware.

In order to operate independently it is necessary for each AP instantiation 'X' and each STA instantiation 'W' to have a separate MAC address. A related problem is solved for the IEEE802.11 IBSS mode by using local administered MAC addresses. In the present invention, the concept is extended to include the mesh nodes operating in ESS modes. Since the MAC addresses are created dynamically, it is necessary to ensure that no two identical values are assigned within the entire mesh. This is achieved by the following method: First the MAC address for the AP instantiation 'X' is set equal to the globally unique MAC address of the mesh node equipment. Then the same MAC address is masked by ANDing with the binary bit pattern:

000000000000000011111111111111111111111111111111

and setting the "locally administered address" bit. The resulting number forms the starting point for allocation of STA address: the "Base STA MAC". Each time a new STA is instantiated a new MAC address is created by the following method:

First the value 000000000000000100000000000000000000000000000000is added to the Base STA MAC to create an "Aspirant STA MAC". Then the Aspirant STA MAC is compared with all MAC addresses that the mesh node knows to the active. If a match is found a new Aspirant STA MAC value is created by applying the same addition operation to the existing Aspirant STA MAC. This process is repeated until a value is obtained which is not known to be active. At this time the value becomes an "Assigned STA MAC" and is used for the STA instantiation.

In the event that, subsequently, the mesh node becomes aware that another device is using a value that conflicts with an Assigned STA MAC, then that STA instantiation will be immediately removed and replaced by a new instantiation.

BACKGROUND TO 2ND INVENTION

We also disclose a second invention relating to systems which share a limited resource between a group of devices co-operating according to the first invention in such a way that certain members of the group may get different portions of the resource compared to other members. This is known as resource allocation. The present invention describes a method and apparatus whereby such resource allocation may be achieved effectively across multiple interconnected networks, especially wireless networks. In the case of a Wireless LAN, an example of a limited resource is access to the wireless medium for transmission purposes. One way to view this is that within a fixed time interval, a limited amount of data may be transmitted in total and co-operating members are each allocated an opportunity to transmit only a certain amount of data from time to time.

Considering the allocation of transmission opportunities, in some systems such allocation is coordinated by a single entity using some pre-determined strategy. This is called the "coordinated approach". In other cases the group members compete for opportunities to transmit without a single point of coordination. This is called the "competitive approach". The competition rules may be altered to allow some group members an improved chance to win and hence obtain a larger share of the resource.

A system which uses both the coordinated and competitive approach' is called a Hybrid Coordinator. In a typical example, the coordinated and competitive modes of access alternate in time, with a portion of time allocated to coordinated access and a portion allocated to competitive access. The time periods alternate continuously and may be of fixed relative duration or may vary. Because the time periods repeat in time a convenient method used to show such operation is to draw successive periods in a circle as shown in Figure 10.

Figure 10 illustrates two periods of time 'AA' and 'AB' which alternate repeatedly. For example 'AA' could be the period when coordinated operation is enforced and 'AB' the period where competitive operation is allowed. This notation will be used in further figures describing the invention.

Consider a single wireless LAN organized as shown in Figure 11. with a base station 'AD' and a number of wireless mobile terminals 'AC' (hereafter "STAs"). This is typical of wireless LAN implementations. In this case the base station 'AD' controls the wireless LAN operations and co-ordinates the time periods 'AA' and 'AB' (Figure

10). Now consider the situation where there are multiple wireless LANs operating in proximity and with overlapping areas of coverage as shown in Figure 12. Here base station 'AD' is controlling STAs 'AC' and base station 'AF' is controlling STAs 'AE'. However since base stations 'AD' and 'AF' are not co-operating then they are likely to allocate transmission opportunities to STAs 'AC' and 'AE' such that the STAs transmit at the same time. This is a problem because simultaneous transmission is likely to prevent effective communication when all devices share the same radio frequency.

If the base stations are connected together in some way such as a mesh configuration overall co-ordination is possible. An example of a mesh configuration is shown in Figure 13. In this example each co-ordinating node 'AG', 'AH', 'AI', 'AJ' is co-ordinating a separate wireless LAN but each is in communication with the others through a wireless or wired link. In the case of 'AH' communicating to 'AJ' or 'AG' the communications is performed indirectly through 'AI'.

The present invention is a method by which multiple coordination nodes (one example of a node being a base station) can allocate resources in time so that coordination occurs across the group of nodes rather than at a single node. The present invention includes a method in which the information to perform distributed allocation is shared by all nodes so that there is no single point of co-ordination. The shared knowledge and coordination responsibility is termed a Virtual Hybrid Coordinator.

The method for the present invention can be described using the concept of concentric rings of allocation. Each node is allocated to a ring level starting at ring 0 and increasing monotonically. Each allocation ring is divided into an arbitrary number of time periods with each time period encompassing a set of rules for transmission. Examples of time period categories are "coordinated period", "competition period" and "no transmit period" although other categories may be used.

When the first node (Node 0) starts it establishes a regular time interval and divides that time interval three sections:

- A coordinated period during which the node allocates transmission resources
- An unallocated period during which no transmissions occur by the node or its associated stations in the case of a base-station node
- A competition period during which uncoordinated communications may occur

This initial allocation ring is shown in Figure 14. Where time period 'AM' is the coordinated period, 'AK' is the unallocated period and 'AL' the competition period. The length of period 'AM' when compared to 'AK' depends on the total allocated resource as determined by the node.

When a second node (Node 1) is started it learns the current ring allocation and timing from Node 0 and establishes a second allocation ring with the start point later in time through the first allocation ring. In its initial state the allocation ring for Node 1 comprises two notional periods: an unallocated period 'AK' and a competition period 'AL' as shown in Figure 15. The knowledge of both rings in held by both nodes. If Node 1 decides that it wants to allocate some transmission time it changes its ring allocation to include a coordinated period of appropriate length and informs Node 0 of the change. Now the shared allocation rings are as shown in Figure 16. using the same notation as Figures 14 and 15.

As more transmit allocations are made the length of the coordinated period for either Node 0 and Node 1 might be such that the allocation period would overlap with the competition period of the other ring. This potential situation is shown in Figure 17. where the coordinated period 'AM' of ring 1 has extended to overlap the competition period 'AL' of ring 0 creating a conflict period 'AN'. To prevent this overlap a Node which is extending its coordinated period by allocating more transmit time must insert a "no-transmit" period into its ring corresponding to transmission allocations of other rings. Therefore, according to this invention Node 1 would reorganize its ring as shown in Figure 18 where period 'AO' has been allocated as a "No Transmit" period for allocation ring 1. Node 1 will inform Node 0 to maintain common knowledge of the ring allocation. The scheme may be extended to include an arbitrary number of nodes and rings provided that all nodes can communicate and maintain a common copy of the allocation ring information. As new nodes are included, the start point for each new allocation ring is chosen so as to subdivide the ring in time. According to one embodiment subdivision occurs evenly so that, for example, using angle round the circle in the diagrams, the first ring is started at position 0°, the second ring at position 180°, the third ring at position 90°, the fourth at position 240°, the fifth at position 45" as so on.

According to the present invention, communication of the shared information between the nodes occurs by each node transmitting its entire knowledge of the allocation rings to any other nodes to which it is connected and which are within range. When a node changes its allocation ring it sends a message showing the revised allocation ring. The revised information is forwarded by other nodes until it has propagated to all the participating nodes. The preferred embodiment describes a method for resolving the case where two nodes simultaneously update their allocation rings with different information.

PREFERRED EMBODIMENTS OF THE SECOND INVENTION

One embodiment of the second invention can be created according to the provisions of the IEEE802.11 wireless standard (ISO-IEC8802-11 ANSI-IEEE std 802.11-1999edn) including subsequent variants and modifications that are work in progress.

In this embodiment a plurality of access point devices are connected together in such a way as to be able to communicate with each other. A message called the Allocation Descriptor (AD) is passed from one access point to others. This message includes a description of every allocation ring known to the sending access point. The communications channel provided between the access point is called the APCC (Access Point Communications Channel). The method of providing such APCC could be wired or wireless.

When operating normally, each access point will transmit an AD message via the APCC to all other access points. The AD message includes a description of its current allocation ring status. Such AD messages will be sent out at regular intervals such as every 10 seconds. According to the invention when an access point starts, it will attempt to detect other access points by listening for ADs via the APCC for a period such as 20 seconds. If other access points are operational, the new access point will learn the number and status of all the allocation rings from the AD messages that are received. If no other access points are detected the new access point will presume to be the first one and will establish a new allocation ring. If other access points are detected the new access point will takes the existing allocation ring information, and add a new ring for itself. In either case the new access point will start to send AD messages containing a copy of all the ring information on a regular basis.

The access points must be time synchronised to enabled them to implement the time periods of the allocation ring effectively. Time synchronization is achieved by each access point maintaining a 64 bit time value called "Sync-Time" which counts up once per microsecond. The value of Sync-Time is updated according to the AD messages. Each AD message includes the 64 bit Sync-Time value of the sender. When an access point starts it sets the Sync-Time value to '0'. However, if it receives any AD message with an adjusted timestamp value greater than its own current value, it will update its own value to equal the received value. The received value is adjusted to compensate for expected delay in transmission and time delay from reception to processing. By this method all nodes obtain a time stamp value synchronised to within a few microseconds.

According to the rules of IEEE802.11, each access point must send beacon messages on a regular basis. According to the present invention each access point transmits a beacon frame that contains a DTIM1 at the start point of its allocation ring and may transmit more beacons at equal intervals around its allocation ring. Furthermore, IEEE802.11 allows each access point to indicate in its beacon frame the duration period for a coordinated phase and a competitive phase (referred to in the standard as "Contention free period" and "contention period" respectively). Therefore according to the invention the access point transmits the information corresponding to the state in its allocation ring. Note that the IEEE802.11 contention free period might span multiple beacons. This is accounted for by transmitting multiple beacons during the allocation ring. The AD message must provide information about the number of beacons sent in each ring. This information is used to allocate "no transmit" periods and also to determine the start positions to new rings in a non conflicting manner.

The effect of the invention can be summarised in the context of IEEE802.11 systems as follows:

- Each cooperating access point transmits its beacons in such a way that those beacons are spaced out in time relative to each other and do not collide
- Each access point defines and supports a contention free period and a contention period.

[1] See IEEE802.11 Standard

- The "no transmit" periods are known by the access points due to sharing of AD messages. Thus access points do not transmit during times when other access points are transmitting beacons or allowing contention mode operation
- The allocation of transmit opportunities during overlapping contention free periods is indicated in the allocation rings thus efficient and predictable use of the available transmit time can be achieved

An example of allocation rings and corresponding transmit events for two overlapping access points is shown in Fig 19. Study of the diagram illustrates that there are four beacons per cycle of the allocation ring. The coordinated period for each ring starts immediately after the beacon which is aligned to the ring start point. The competition period for the ring occurs immediately before the same beacon. "No transmit" periods are allocated where there would be conflict between transmissions of the two rings. The method for determining "no transmit" periods is based on priority such that:

- Beacons are highest priority
- Competition period is next priority
- Coordinated period immediately following the start of a ring takes next priority
- Coordinated period already in effect takes lowest priority

The AD information comprises a set of descriptor tables, one for each node operating in the system. Each descriptor comprises the following information:

- Timestamp for start of ring relative to ring 0
- Number of microseconds allocated to coordination period
- Number of microseconds allocated to competition period
- Number of beacons in allocation ring
- Timestamp of current change if applicable

When a node wishes to have more allocation it checks its copy of the rings to confirm that the allocation space is feasible and then updates its own ring and starts sending the modified information in the AD messages. Other nodes receiving the updated AD will update their own stored information and resend the new information immediately

without waiting for the scheduled interval. Because the AD contains the timestamp of last change the nodes can determine if the changed information is more recent than their own stored version.

It may happen that two nodes make such adjustments to their ring information simultaneously (or nearly simultaneously) creating a potential conflict. Such a conflict is resolved in the following manner: All changes are notified in AD messages which contain the Time-Sync value for the change. Whenever such a change AD is accepted by another node it stores the Time-Sync value as the "Last change" time and forwards the AD. When a change AD is received with a Time-Sync value earlier than the current value of "Last change" then that AD is discarded and not forwarded. Therefore when a node wishes to change its allocation it starts advertising by sending modified ADs but does not put the change into effect for a period of time proportional to the number of rings active. If another node has made a change at almost the same time then only the most recent message will propagate to all the nodes. The node that wins will see its own AD return but the node that loses will see that its information has been discarded and must not put its requested change into effect. There is a small chance that the timestamps will be exactly equal. In this case both updating nodes will receive an AD with the change from the other node. They will detect the equal time stamp and then should both re-issue the request. The likelihood of a second collision is extremely low due to differences in network propagation time and the nodes can repeat until one node wins.

CLAIMS FIRST INVENTION

1. A network node arranged to act as a communicationshub between a first set of devices and a second set of devices, wherein the node comprises master means and servant means and wherein the master means is arranged to co-ordinate data transmissions between the node and the first set of devices, and wherein the servant means is arranged to be co-ordinated by another network device for data transmissions between the node and the second set of devices.

2. A network node as claimed in claim 1, wherein the master means is arranged to contol the data transmissions between the master means and the first set of devices, and/or the servant means are arranged to be controlled by another network device for data transmission between the node and the second set of devices.

3. A network device as claimed in claim 1 or claim 2, wherein the another network device is a neighbouring network device.

4. A network device as claimed in claim 3, wherein the neighbouring network device is a second network node arranged to act as a communications hub for one or more sets of devices, and wherein the first and second network node are arranged to co-ordinatelcontrol data transmissions to diminish data transmission interference between the various sets of devices.

5. A network node as claimed in claim 4, wherein the second network node is a node according to claim 1 having both master and servant means.

6. A network node as claimed in any preceding claim, wherein the network node comprises detection means arranged to detect the presence of one or more neighbouring second sets of devices, and apportion a corresponding number of servant means to be co-ordinated/controlled by each neighbouring second set of devices.

7. A network node as claimed in any preceding claim, wherein the network node comprises detection means arranged to detect the presence of one or more neighbouring network nodes each co-ordinating/controlling a set of devices, and wherein the node is arranged to apportion a corresponding number of servant means to be co-ordinated/controlled by each neighbouring network node.

8. A network node as claimed in claim 6 or claim 7, wherein the network node is arranged to dynamically apportion a corresponding number of servant means, as and when neighbouring second sets of network devices/nodes are detected by the detection means.

9. A network node as claimed in any preceding claim, wherein the node master means and the or each servant means each have a different network address.

10. A network node as claimed in claims 6-9, wherein the node is arranged to dynamically create a network address for each servant means, as and when neighbouring sets of network devices/nodes are detected by the detection means.

11. A network node as claimed in any preceding claim, wherein the or each servant means is created in software.

12. A network node as claimed in claim 11, wherein each of the servant means share the use of the same transmission hardware.

13. A network node as claimed in any preceding claim, wherein the master/servant means is implemented in hardware, software or a combination thereof.

14. A network node as claimed in any preceding claim, wherein the master/servant means comprises one or more processors programmed by software *to* perform the master/servant functionality.

15. A network node as claimed in any preceding claim, wherein the master/servant means comprises memory means which is used as a buffer store to store data transmissions until the data transmissions are authorised for continued transmission.

16. A network node as claimed in any preceding claim, wherein the master means and the or each servant means are arranged to pass data between one another.

17. A network node as claimed in claim 16, wherein the network node is arranged such that the data passed between the master and the or each servant means stays within the network node.

18. A network node as claimed in any preceding claim, wherein the network node comprises a MAC bridge to allow data to pass between the master means and the or each servant means.

19. A network node as claimed in any preceding claim, wherein the first and/or second set of devices comprises one, two or more devices.

20. A network node as claimed in any preceding claim, wherein the first and/or second set of devices comprises one, two or more network nodes.

21. A network node as claimed in any preceding claim, wherein the first/second set of devices comprises one, two or more network nodes according to claim 1.

22. A network node as claimed in any preceding claim, wherein the first set of devices comprises a plurality of devices and the node is arranged to act as a communications hub for data transmissions within the first set of devices.

23. A network node as claimed in any preceding claim, wherein the node is arranged to also utilise the data transmissions for node specific functions.

24. A network node as claimed in claim 23, wherein the network node is a home entertainment system arranged to play the data content transmission provided from the network.

25. A network node as claimed in any preceding claim, wherein one or more of the first set of devices conform to a Network Standard.

26. A network node as claimed in any preceding claim, wherein the network node is arranged to conform to a Network Standard.

27. A network node as claimed in any preceding claim, wherein the master means is arranged to conform to the IEEE802.11 Standard.

28. A network node as claimed in any preceding claim, wherein the node comprises wired transmission means for transmissions between the node and the first/second sets of device.

29. A network node as claimed in any one of claims 1 to 27, wherein the node comprises wireless transmission means for transmissions between the node and the first/second sets of device.

30. A network node as claimed in claim 29, wherein the node is arranged to use the same wireless transmission means for wireless transmissions between both the first and second set of devices.

31. A network node is as claimed in any preceding claim, wherein the network node is an area network access point device.

32. A network node is as claimed in any preceding claim, wherein the network node is a mobile telecommuncations network device.

33. A network comprising a network node as claimed in any preceding claim.

34. A network as claimed in claim 33, wherein the second set of devices comprises a second network node arranged to co-ordinate/control data transmissions between the first network device servant means and the second set of devices, and the first network device servant means is arranged to be co-ordinated/controlled for data transmissions between the first and second network nodes by the second network node.

35. A network as claimed in claim 34, wherein the second network node comprises master means and the second network node master means is arranged to co-ordinate/control data transmissions between the second network node master means and the first network node servant means.

36. A network as claimed in any one of claims 33-35, wherein the network is a computer network and the node is an access point device and the first sets of devices are one or more wireless terminals.

37. A network as claimed in any one of claims 33-36, wherein the network is arranged to conform to the IEEE802.11 Standard.

38. A network as claimed in any one of claims 33-37, wherein the network is a telecommunications network and the node a cellular base station, and the first set of devices are one or more portable telecommunicationshandsets.

39. A method of providing network connectivity between a first and second set of devices connected by a network node and wherein the node is provided with the facility to co-ordinate data transmissions with the first set of devices and have data transmissions with the second set of devices co-ordinated by another network device.

40. A method of generating a mesh network by providing a network node arranged to act as a communications hub between a first set of devices and a second set of devices, wherein the node comprises master means and servant means and wherein the master means is arranged to co-ordinate data transmissions between the node and the first set of devices, and wherein the servant means is arranged to be co-

ordinated by another network device for data transmissions between the node and the second set of devices.

41. A network node as hereinbefore described with reference to the accompanying drawings.

42. A network as hereinbefore described with reference to the accompanying drawings.

43. A method of providing network connectivity as hereinbefore described with reference to the accompanying drawings.

44. A method of generating a mesh network as hereinbefore described with reference to the accompanying drawings.

45.

CLAIMS SECOND INVENTION

1. A method for control of wireless networks using a Virtual Hybrid Coordinator as described according to the second invention

QOSOOI : Sheet ▮/ 8

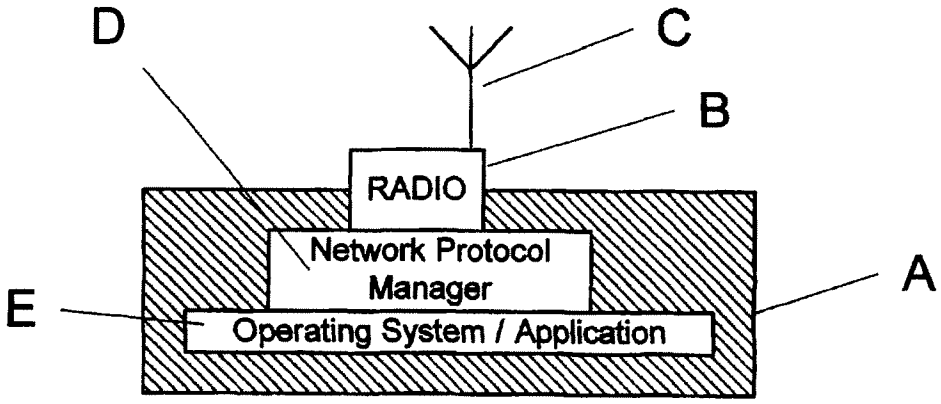
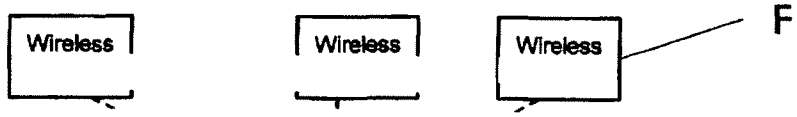
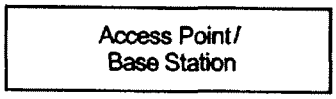


Fig ▮





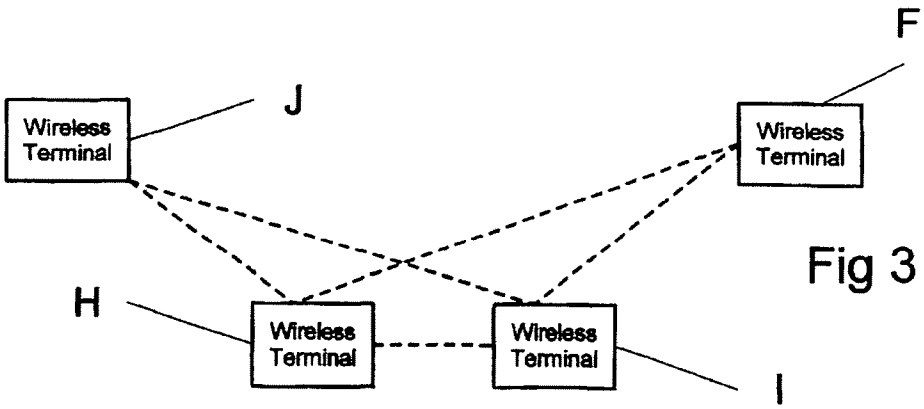


Fig 3

QOS001 Sheet 2 / 8

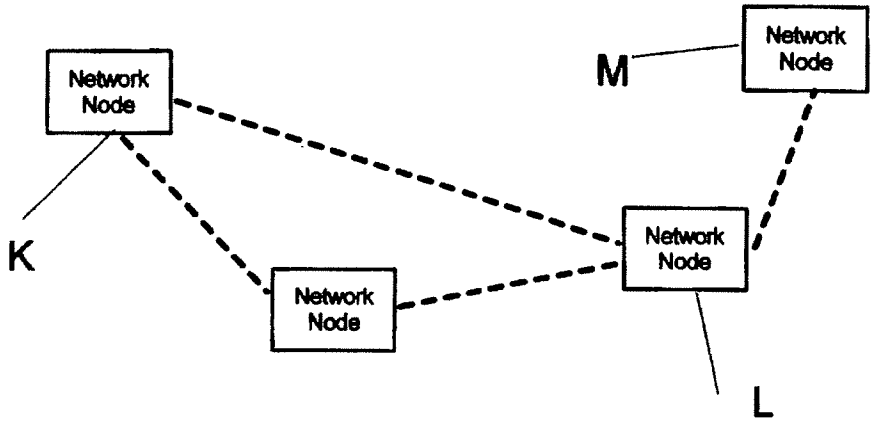


Fig 4

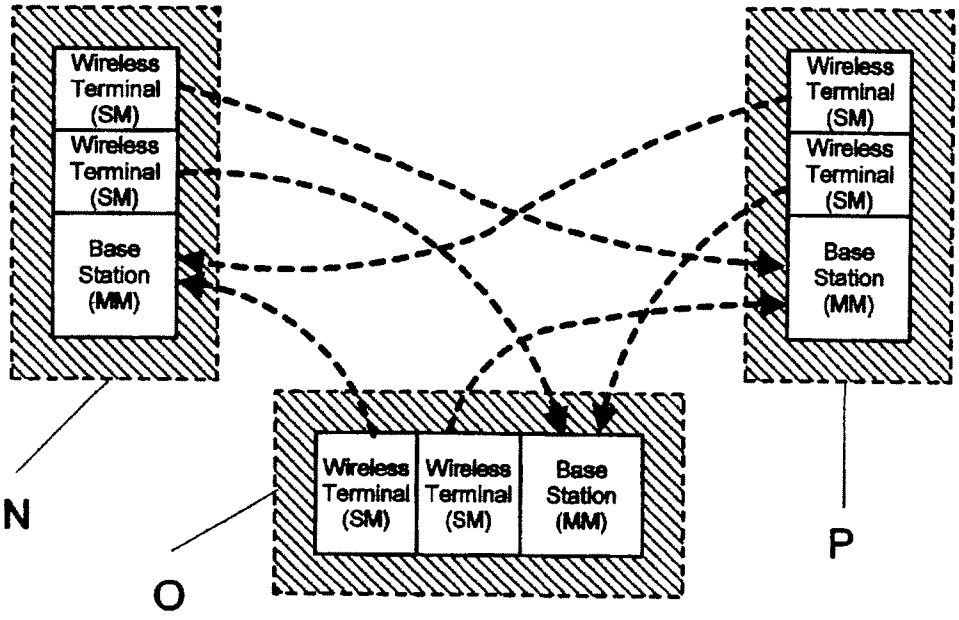


Fig 5

QOS001 Sheet 3 / 8

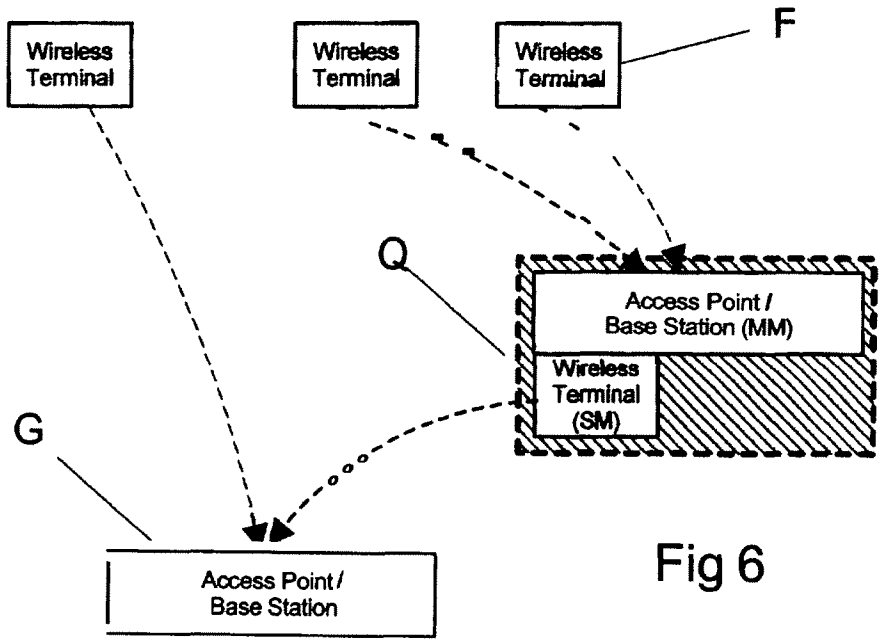


Fig 6

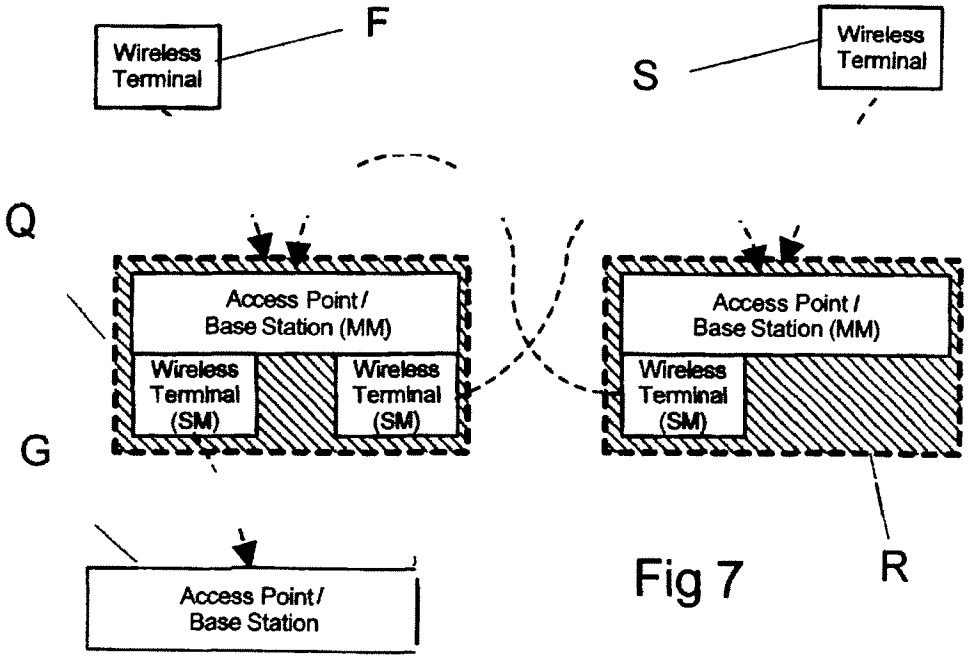


Fig 7

QOS001 Sheet 4 / 8

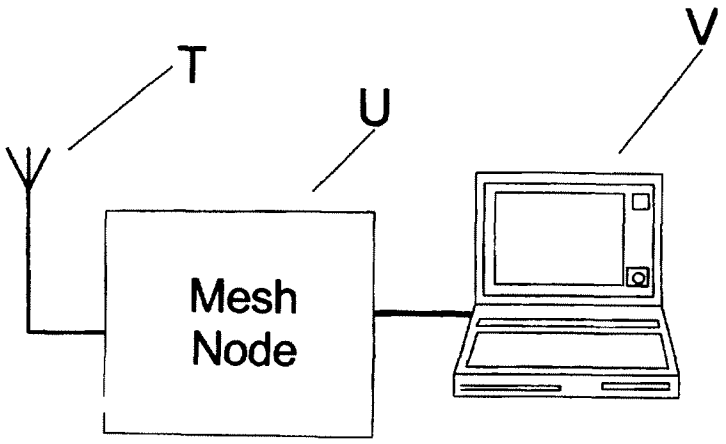


Fig 8

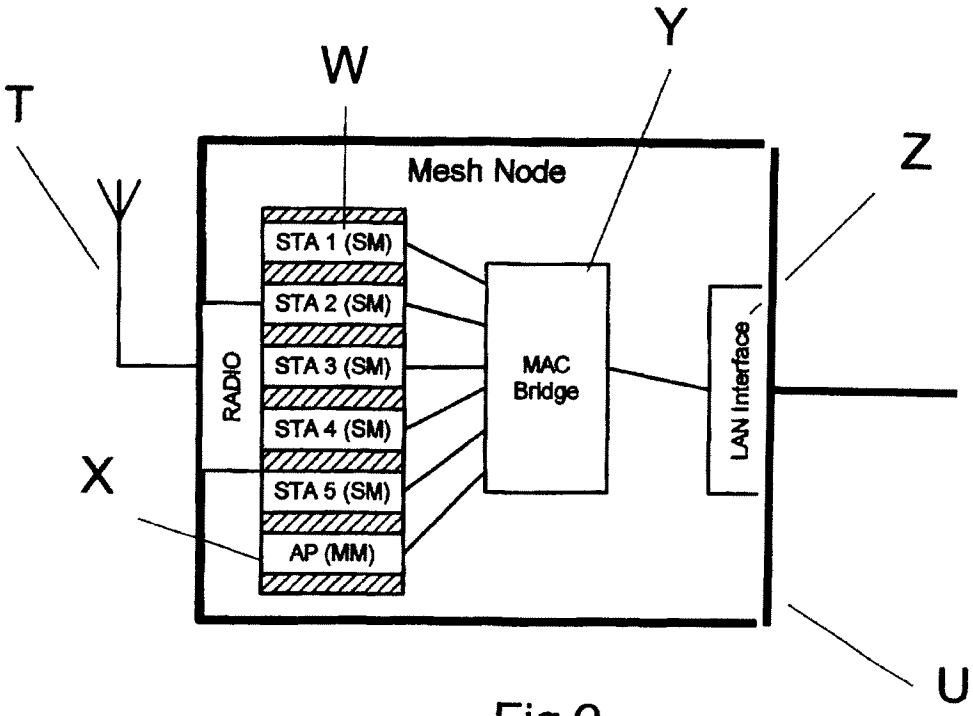


Fig 9

QOS001 : Sheet 5 / 8

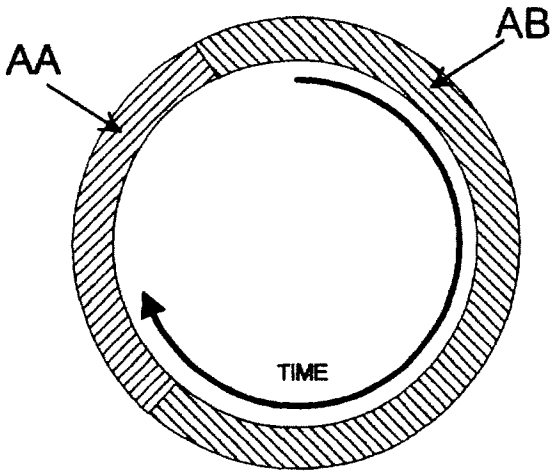


Fig 10.

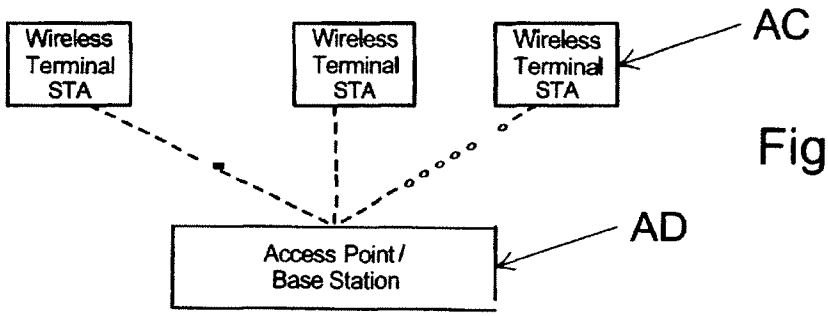


Fig 11

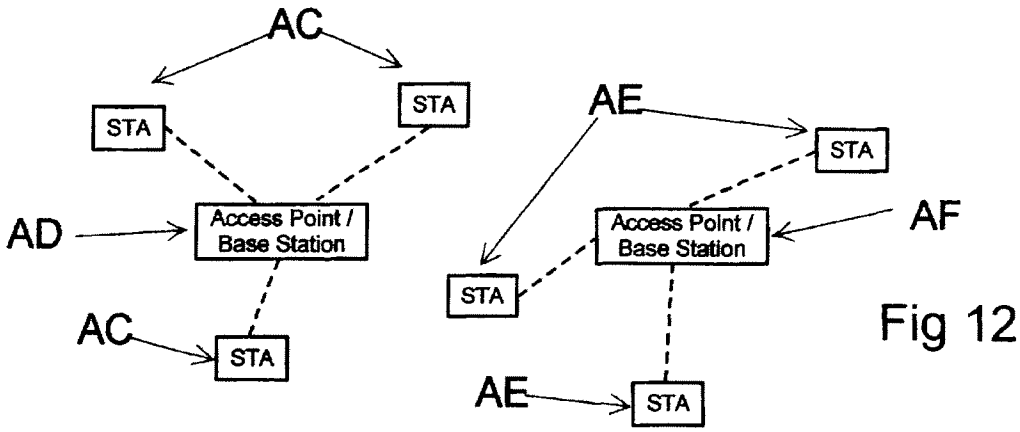
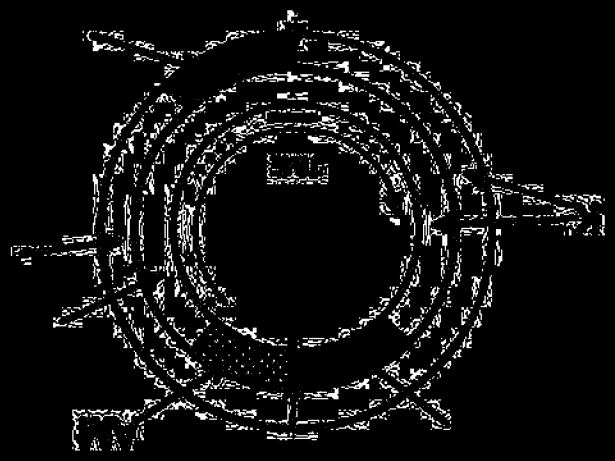
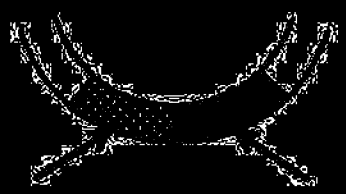
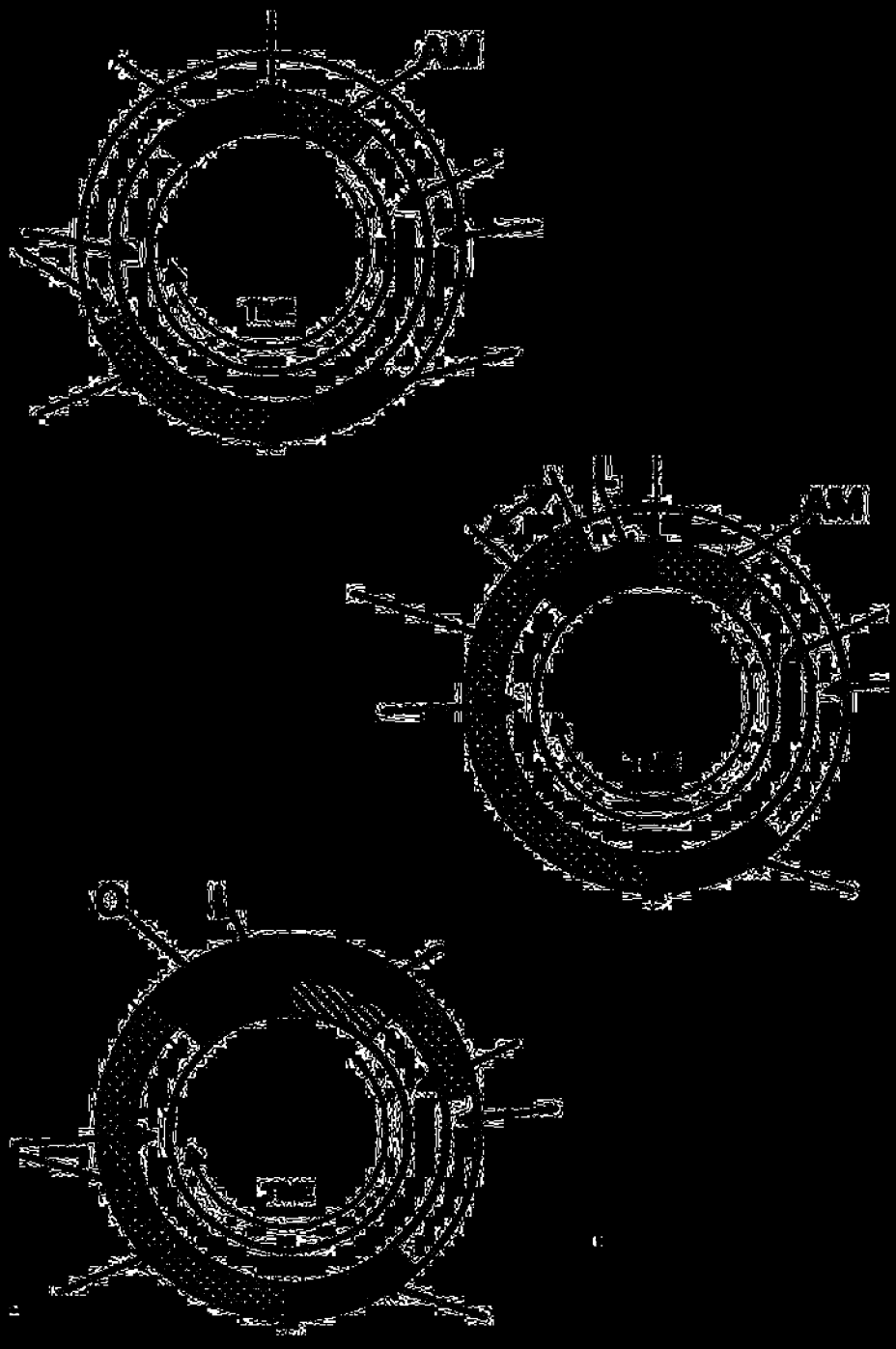
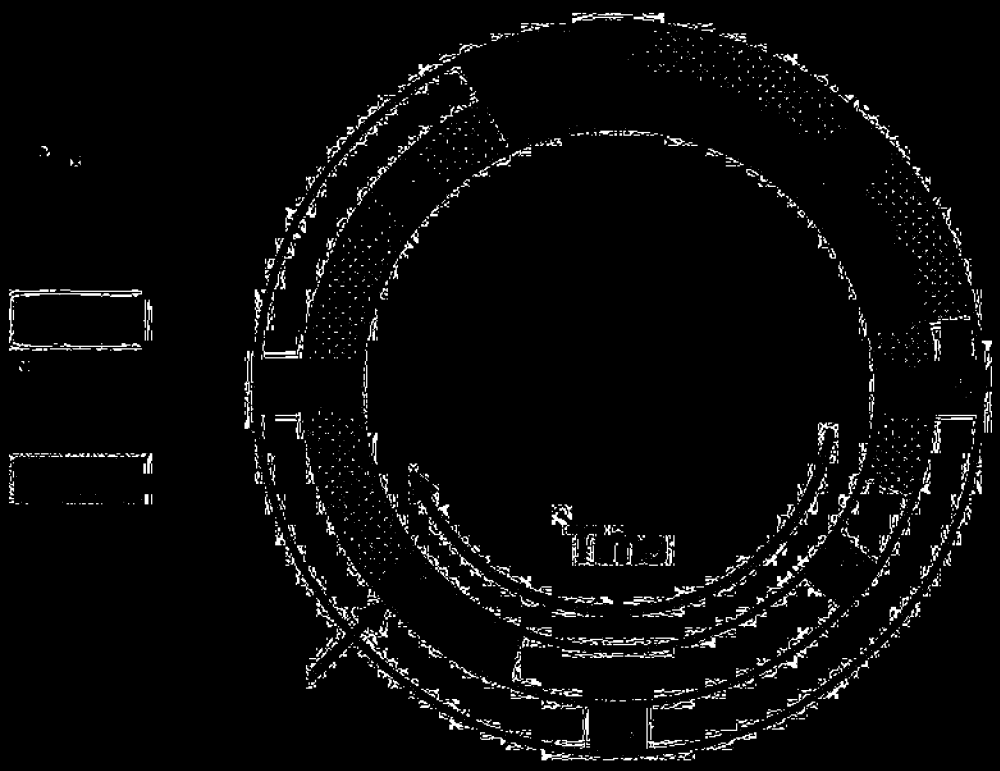


Fig 12









INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 03/00624

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04L12/56 H04L12/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04L H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
WPI Data, PAJ, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	EP 1 107 522 A (ERICSSON TELEFON AB L M) 13 June 2001 (2001-06-13) abstract page 1, paragraph 1 -page 6, paragraph 42 page 6, paragraph 52 page 10, paragraph 70 page 11, paragraph 81 claims 1,2 --- -/--	1-3, 6-14, 16-23, 25-27, 29-44

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the International filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 June 2003	16. 07. 2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Vaskimo, K

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INTERNATIONAL SEARCH REPORT

Int lonal Application No
F../GB 03/00624

C.(Continuation) DOCUMENTS CONSIDEREDTO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 01 69869 A (NOKIA CORP ;NOKIA INC (US)) 20 September 2001 (2001-09-20) page 1, line 5 -page 7, line 10 page 9, line 5 -page 10, line 12	1-3, 9-14, 16-23, 25-27, 29-44
A	---	6-8
X	JENNIFER BRAY & CHARLES F STURMAN "BLUETOOTH - Connect Without Cables" 2001 , PRENTICE HALL PTR , UPPER SADDLE RIVER, NEW JERSEY, USA XP002243377 page 42, paragraph 4.2 -page 45, paragraph 4.4 page 52, paragraph 4.6.2 -page 53, paragraph 4.6.3 page 82, paragraph 5.6 -page 84, paragraph 5.7 page 357, paragraph 19.1.4 -page 363, paragraph 19.2 page 426, paragraph 23.5 -page 428, paragraph 23.6	1-3, 9-14, 16-23, 25-27, 29-44
A	---	6-8
A	WO 02 08857 A (CADENCE DESIGN SYSTEMS INC) 31 January 2002 (2002-01-31) abstract page 1, line 7 -page 3, line 9 page 10, line 6 -page 11, line 2	1,27,31, 33,36-38

INTERNATIONAL SEARCH REPORT

national application No.
PCT/GB 03/00624

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-3, 6-14, 16-23, 25-27, 29-44

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-3,6-14,16-23,25-27,29-44

A network node arranged to act as a communications hub between sets of devices, where said node comprises master means and servant means, where said master means is arranged to coordinate data transactions between said node and a first set of devices, and where said servant means is arranged to be coordinated by another network device for data transmissions between said node and a second set of devices.

1.1. Claims: 1,6,7,8

A network node arranged to act as a comnunications hub between sets of devices, where said network node is arranged to detect the presence of other sets of devices, and to apportion servant means to said other sets of devices.

1.2. Claims: 1,9,10

A network node arranged to act as a comnunications hub between sets of devices, where the master means and the servant means in said node each have different network addresses.

1.3. Claims: 1,31,36,38

A network node arranged to act as a comnunications hub between sets of devices, where said node operates as an access point device.

2. Claims: 1,15

A network node arranged to act as a communications hub between sets of devices, where said node comprises master means and servant means, where said master means is arranged to coordinate data transactions between said node and a first set of devices, where said servant means is arranged to be coordinated by another network device for data transmissions between said node and a second set of devices, and where said node comprises memory means used to buffer data transmissions until said data transmissions are authorised for transmission.

3. Claims: 1,28

A network node arranged to act as a communications hub between sets of devices, where said node comprises master means and servant means, where said master means is arranged

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

to coordinate data transactions between said node and a first set of devices, where said servant means is arranged to be coordinated by another network device for data transmissions between said node and a second set of devices, and where said node comprises wired transmission means for transmissions with the sets of devices.

4. Claim : 45

A method for control of wireless networks using a Virtual Hybrid Coordinator.

5. Claims: 1,4,5

A network node arranged to act as a communications hub between sets of devices, where said node comprises master means and servant means, where said master means is arranged to coordinate data transactions between said node and a first set of devices, where said servant means is arranged to be coordinated by another network device for data transmissions between said node and a second set of devices, and where network nodes of said sets of devices coordinate and control data transmissions to diminish data transmission interference.

6. Claims: 1,23,24

A network node arranged to act as a communications hub between sets of devices, where said node comprises master means and servant means, where said master means is arranged to coordinate data transactions between said node and a first set of devices, where said servant means is arranged to be coordinated by another network device for data transmissions between said node and a second set of devices, and where said node is a home entertainment system arranged to play the data content transmission provided from the network.

Please note that all inventions mentioned under item 1, although not necessarily linked by a common inventive concept, could be searched without effort justifying an additional fee.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date